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Research Article

A methodological framework for addressing environmental problems on aged transport infrastructure

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Abstract

While the environmental impacts of new road and motorway construction are examined in detail as part of the Environmental Impact Assessment (EIA) process, far less attention is generally paid to existing structures, some of which have been in operation for decades with no environmental assessment ever carried out. In this paper, a framework for an audit of the assessment of environmental burdens from older transport infrastructure is presented. Its main objective is to set up a systematic and comprehensive approach to the preventive identification of problematic locations on the existing road network to prepare proposals for practical and feasible upgrading or optimization measures that can be addressed within the routine repairs and small reconstructions. It primarily deals with the setup of the whole process, starting with the preparation of the background for the assessment, the field survey procedure, the design of possible measures and their subsequent monitoring. The audit concept identified a total of 14 key problem domains representing individual environmental problems, for which methodological sheets were prepared. However, this is not a rigid number; the whole framework is conceived as an open system allowing for the addition of new topics or possible methodological adaptations to the practices common in other countries or in transport sectors other than roads. The audit is currently considered as a voluntary tool applicable on the state owned transport network, thus the practical usage is in the hands of the state administration and infrastructure operators.

Key words: Auditing, biota, environmental burden, existing road network, measures, soil and water, upgrading

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Research highlights

- Roads built before 1992 (in the Czech Republic) were not subject to any environmental impact assessment.
- The objective of the framework for environmental assessment of older roads is designed to highlight existing impacts needing to be addressed and the subsequent elaboration of practical optimisation measures.
- Only topics that are not part of other agendas are addressed (impact on public health, traffic safety) while the task is not just to check compliance

with limits by legislation but rather to produce recommendations to meet best practice available.
- The framework is designed as an open system, allowing for the addition of new topics or possible methodological adaptation to practices common in other countries or in transport sectors other than road.
- The audit is currently considered as a voluntary tool applicable on the state owned transport network, thus the practical usage is in the hands of the state administration and infrastructure operators.

Introduction

The issue of environmental protection in relation to transport infrastructure is a very, complex, and constantly evolving topic. The first formal Environmental Impact Assessment (EIA) system was established by the US National Environmental Policy Act in 1970 (Cashmore 2004). EU introduced Environmental Impact Assessment Directive (85/337/EEC) in 1985 and EIA was later adopted also in many other countries of the world (Petts 1999; Freitas et al. 2017), which has led to a deeper consideration of the environmental issues arising from the construction and subsequent operation of new road and motorway projects. However, despite the large infrastructure deficit typical of Central and South-Eastern European countries that is only slowly being eliminated (Rosik et al. 2018; Papp et al. 2022; Komornicki and Goliszek 2023), many existing roads were built before the EIA legislation came into force. Most of these constructions have a very long historical past and were built at a time when environmental impacts were not yet understood. The impact on environmental components was virtually not addressed at the time of their construction, or only to a very limited extent, so their real environmental impact might be much higher than if these structures were built now. These are a broad range of issues (Forman et al. 2003) that include territorial impacts (Ortega et al. 2015; Goldmann and Wessel 2020), soil erosion and drainage of contaminated water from the road (Folkeson et al. 2009; Makowska and Mazurkiewicz 2016; Rivett et al. 2016; Jandová et al. 2020), the condition of roadside vegetation (Phillips et al. 2019; Salisbury et al. 2022; Cabral et al. 2023), noise and pollution from vehicle traffic and in particular various impacts on biodiversity such as issues of ecological connectivity and the migratory permeability of roads for wildlife (Cumming and Tavares 2022; Oliveira Gonçalves et al. 2022; Papp et al. 2022), the condition of fencing and barriers for animals (Shepard et al. 2008; Beyer et al. 2014), animal-vehicle collisions (Niemi et al. 2017; Arca- Bíl et al. 2019; Rubio et al. 2023) or long-term persistence of wildlife populations (Kuehn et al. 2006; Benítez-López et al. 2010; Barbosa et al. 2020; Barrientos et al. 2021). Some authors analysed the description of the environmental problems related to transports in a holistic way, which include a life cycle approach (Erlandsson 2004) or cumulative effects assessment (Jones 2016).

When considering benefits of the transport infrastructure to the landscape, one of the key ideas for improving their landscape functions is integrating them within the system of green infrastructure (Skokanová and Slach 2020; Fňukalová et al. 2021). In recent years, emphasis has also been placed in Europe on the inclusion of green infrastructure and ecosystem services to the spatial planning

(Liquete et al. 2015; Slätmo et al. 2019; Mederly et al. 2020). Green belts along traffic roads leading to the intersection of green networks and traffic networks have great potential, especially in agricultural landscapes (Skokanová et al. 2020). The planting of grassy green belts, shrubs and trees along traffic roads can also have very positive effects on Assessment and Spatial Distribution of Urban Ecosystem Functions (Phillips et al. 2019; Nozdrovická et al. 2020; Včeláková et al. 2023).

However, unlike the EIA procedure for new constructions, the situation for the existing network is not comprehensively and systematically addressed. Only the individual sub-issues, particularly about assessing risks to public health (Fehr et al. 2014; Adamiec, Jarosz-Krzemińska 2019) or road safety (IHT 2008), are regularly addressed. At the same time, however, many sections of the older road network are reaching the end of their operational lives and significant structural or material repairs should be undertaken in the near future. This is a great opportunity to reshape infrastructure to minimalize current as well as future environmental impacts and harmonise its performance with nature conservation requirements.

Thus, there is a lack of tools that would enable a systematic evaluation of existing impacts on the older motorway and road network in relation to environmental components such as water, soil, biota, and landscape and the preparation of proposals for practical and feasible optimization measures that can be implemented within the framework of routine repairs and upgrading of roads. And it should also be a guidance for a detailed analysis of the road's environmental performance before carrying out reconstructions unless a detailed EIA is required for such a project.

The aim of the framework

The aim of this paper is to close the above gap and to propose a framework for a new tool for environmental assessment in relation to older transport infrastructure, namely the Environmental Audit of Transport Infrastructure (hereinafter referred as EADI from Czech "Environmentální audit dopravní infrastruktury"), which:

(a) complements the system of environmental impact assessment (EIA) of transport constructions, mainly focused on new constructions, by the assessment of the impact of existing roads. These were mainly built at a time when environmental protection requirements were not as high as they are now;
(b) extends the current systems for monitoring the impact of transport on public health, traffic safety and the technical inspection system for buildings to include the assessment of impacts on other environmental components, in particular water, soil, biota and landscape;
(c) is aimed at the preventive search for impact situations of the transport infrastructure and the subsequent proposal of optimisation measures to be implemented mainly in the framework of regular repairs and reconstruction;
(d) provide road managers with an overview of the ongoing optimisation measures implemented on the road network in a regularly recurring mode and provide feedback for planning and for evaluating the effectiveness of the resources spent.

Methodology

The preparation of the draft framework was carried out with regard to the legislation and the real conditions of established management practice in the Czech Republic. The initial stage of the development of the framework was a system analysis of the impact of existing roads on individual environmental components. Subsequently, from the identified environmental impacts, to avoid duplication those that are not standardised in other assessment processes were selected, while for the remaining ones the key problem areas to be addressed in the audit were defined. Through system analysis, the impact of existing roads is assessed comprehensively, taking into account the surrounding environment components. This analysis provides a holistic view of the potential consequences and allows for appropriate mitigation measures to be proposed. A separate methodology sheet was then drawn up for each key issue area, defining the treatment of the issue in five stages:

I. Introductory phase – basic analysis of the situation, screening and scoping, preparation of background documents;
II. Field survey;
III. Evaluation of results and identification of impacts;
IV. Proposal of mitigation measures;
V. Conclusion.

The last step was the elaboration of general recommendations and the proposal of a procedural course of action for the practical implementation of the audit results, including recommendations for the contracting authorities (infrastructure managers) who should further work with the audit results.

Principles and basic rules for developing an environmental audit methodology

When designing and developing the framework, we applied the following rules as much as possible:

1. Focus on current impacts reduction and prevention of long term effects – the goal is to find problematic impact sites so as to solve reduce environmental consequences. Therefore, it is proposed to carry out a comprehensive assessment for each sub-section of road and to include this tool as a regular part of roads' management.
2. Independence from legislative requirements – the aim is not just to check compliance with limits by legislation but rather to meet best practice available.
3. Practical orientation – the audit is based on the assessment of selected situations and its outputs are focused on realistic mitigation measures that can be implemented mostly within the framework of routine maintenance or basic reconstruction of the road. The environmental audit is in no way analogous to the EIA process; it does not seek a theoretical

description of possible impacts and synergies, but rather a search for practical proposals to mitigate traffic impacts.

4. Efficiency of processing – an environmental audit fundamentally avoids duplication of assessment. It therefore does not include procedures that are already regularly implemented today.
5. Respect for local conditions – given the considerable variability of both roads and surrounding natural conditions, the EADI is designed as an open system whose basic methodological approaches must always be adapted to the specific local situation. Therefore, at the beginning of each EADI, a screening and assessment of the local situation should be carried out and the scope and methodology of the assessment modified accordingly.
6. Spatial extent – the audit focuses on the situation in the open landscape and thus it is determined that the EADI is not intended to assess the situation in the urban areas.

Systematic analysis of the environmental impact of existing roads

The initial stage of the framework development was a systemic analysis of the impact of existing roads on individual environmental components. For defining the EADI framework, a matrix was proposed:

- The vectors that transmit the impact of road on the components of the environment (see Table 1). The advantage of vectors is that they are in most cases quantifiable (noise, emissions, concentrations of substances in water, etc.).
- Environmental components according to the EIA outline – see Table 2.

The individual impacts identified (Table 3) were investigated in terms of their inclusion in the already regularly ongoing agendas of various government bodies and road managers. In order to avoid duplication and to maxi-

Table 1. Vectors transmitting the impact of road (physical infrastructure + traffic) on the various components of the environment.

Vector		Description
A1	mechanical motion energy	traffic accidents, animal-vehicle collisions, wildlife mortality
A2	acoustic energy	noise, noise disturbance of inhabitants and wildlife
A3	light (electromagnetic energy)	light pollution of the environment
A4	transport of airborne substances	dispersion of emissions
A5	transport of waterborne substances	contamination by (a) substances from winter maintenance (b) other substances from traffic
A6	visual perception	disturbance of the human and animal population by the movement of motor vehicles; disturbance of the landscape character
A7	barrier effect	(a) physical, (b) psychological barriers to wildlife and human movement
A8	modified habitats	change in microclimate, distribution of plants and animals; change in land-use and landscape matrix

mise the efficiency of the process, several sub-issues were not included in the EADI, because there is an established monitoring framework for them. Such sub-issues are:

- public health impact assessment,
- road safety assessment,
- assessment of the technical condition of structures on road.

EADI is thus focused on impacts that are not yet systematically monitored although they may be in relation to some of the topics listed above (e.g. road safety assessment with the Animal-Vehicle Collisions). These have been clustered into three areas:

- biota,
- soil and water,
- landscape and cultural heritage.

Table 2. Environmental components according to EIA legislation (Czech law act no. 100/2001 Coll.).

Environmental component		Description
B1	inhabitants	population and public health
B2	atmosphere	atmosphere and climate
B3	noise	noise situation and other physical and biological disturbances (light, vibrations)
B4	water	surface water and groundwater
B5	soil	soil cover
B6	natural resources	natural resources
B7	biota	biodiversity, fauna, flora, ecosystems
B8	landscape	the landscape and its ecological functions
B9	immovable property	immovable property, cultural heritage, architectural and archaeological monuments

Table 3. System analysis of major environmental impacts of roads – matrix of vectors (A) and environmental components (B).

		A1	A2	A3	A4	A5	A6	A7	A8
		Kinetic energy	**Acoustic energy**	**Light**	**Airborne movement**	**Waterborne movement**	**Visual contact**	**Barrier effect**	**Biotope change**
B1	**inhabitants**	traffic accidents	noise disturbance	lighting pollution	imissions	pollution	disturbance	fragmentation	
B2	**air**				emission				
B3	**noise**		noise disturbance						
B4	**water**					pollution			
B5	**soil**				emissions	pollution erosion			
B6	**resources**								
B7	**biota**	collisions mortality	noise disturbance	light pollution	imissions	pollution	disturbance	fragmentation	spread of species
B8	**landscape**		noise disturbance				landscape character	fragmentation	land-use
B9	**property**	direct damage			corrosion of materials	corrosion of materials	landscape character		

Key problem domains

Based on the authors' long-term practical experience and according to the numerous literatures (e.g. Hlaváč et al. 2020; Adamec et al. 2008; Rodrigue 2020; van der Ree et al. 2015), the most serious and frequent risk factors in relation to transport were identified for each EADI area. These are further identified as key problem domains (KPD) and form the methodological basis for the assessment. A list of the individual KPDs which have been addressed in depth in the methodology is presented in Table 4.

Each KPD has defined its own methodological procedure, which is based on the practice standardised for the individual domain addressed. The methodological procedures for individual KPDs are described in detail in the EADI certified methodology (Dostál et al. 2021), a sample of such a methodological sheet is presented in Appendix 1.

The list of KPDs above may not be fixed, EADI is designed as an open system. KPDs form the basis of the assessment and in the EADI they must be assessed compulsorily on all domains from Table 5 despite some the domains may be identified as non-relevant for the assessed section of road. If a different problem domain (e.g., invasive plant species) occurs on any of the assessed sections, it will be either specified directly by the contracting authority or identified in the screening process and included in the assessment.

Each KPD:

- Represents a clear practical problem that requires a concrete practical solution in several places. This is based on the practical focus of the EADI to ensure that realistic optimisation measures are associated with each factor assessed.
- Is a kind of coherent issue with its own methodology and scientific literature as shown in Appendix 1. The recommendations from this literature then also serve as a basis for the design of the measures.
- Is described according to uniform scheme (see Table 5), which is binding in the EADI. If another KPD is added as part of the screening, it will also follow this outline.

Table 4. Set of key problem domains (KPD).

EADI area		Key problem domain		Impact
i	biota	B1	Permeability for large mammals	fragmentation, land-use
		B2	Traffic accidents with wildlife	mortality
		B3	Critical sites for amphibians	mortality, fragmentation
		B4	Migration along watercourses	spread of species, fragmentation
		B5	Concept of fencing	mortality, fragmentation
		B6	Noise protection walls	noise disturbance
		B7	Impacts on small special protection areas	disturbance, spread of species, land-use
ii	soil and water	V1	Road drainage concept	pollution, mortality
		V2	Winter maintenance technology	pollution
		V3	Watercourse fragmentation	spread of species, fragmentation
		V4	Slope instability and landslides	erosion
iii	landscape and cultural heritage	K1	Visual disturbance and landscape character	landscape character
		K2	Accessibility and permeability of the landscape for inhabitants	fragmentation
		K3	Impacts on immovable cultural heritage	direct damage, corrosion of materials

Table 5. Binding scheme of each KPD.

Id	Heading	Description
A	Name	KPD working title
B	Component of Environment	classification within environmental components and subcomponents
C	Characteristics	basic description of the problem area, reasons for the solution
D	Background materials	baseline documents, input for the field investigation
E	Field survey	field survey procedures, monitoring considerations
F	Evaluation criteria	methodological criteria for determining the correct solution
G	Proposal of measures	basic conceptual design for the implementation of practical measures
H	Summary	conclusion for the evaluation in the domain

Workflow for audit processing

Formally, the preparation of the EADI is divided into 5 basic phases. The methodological procedure for each stage is strongly dependent on the environmental problem addressed and is therefore defined within the framework of the methodologies established for the processing of individual KPDs. However, a set of general recommendations can also be established that apply to the individual stages.

I. Introductory phase – basic analysis of the issue, screening, and scoping

- The screening and scoping phase allows for the adaptation of the methodology of work on individual KPDs to specific local situation and ensures variability in the overall approach.
- Based on the input data and other available information, a decision will be made on the possible extension of the assessment to other environmental components (additional KPDs beyond those listed in Table 5).
- In relation to the specific situation, the level of detail of the assessment will be chosen for individual KPDs in relation to individual road features. Depending on the specific assignment, it is possible to evaluate (i) only the objects that are directly related to the KPD in question (this is the basic solution), or (ii) to evaluate all objects of the section (variant solution – where the survey is focused more on the theoretical level) or a combination of both approaches can be used where desirable.
- As a basis for the subsequent field survey, sufficient data should be obtained on the road to be assessed, its immediate surroundings and, if necessary, on the immediately adjacent sections of adjacent roads. The structure of the required data varies from one KPD to another.
- Geographical information systems (GIS) shall be used as much as possible in the data processing.

II. Field survey

- The methodology for the field survey is determined individually for each KPD.
- Common to all field surveys is the need to accurately identify the objects to be assessed on the road. Two procedures are recommended to be applied simultaneously, using: (a) geographical coordinates (most often in

the WGS-84 system), allowing for general use in GIS; (b) positioning (in km) of the road in question – commonly used by road managers.
- Each object evaluated during the field survey is described using predefined forms, which are specified within the individual KPD method sheets – for an example see Appendix 1: Table A1 and completed form in Appendix 2.
- Local knowledge can also provide valuable information, so it is desirable to consider information obtained, from local stakeholders such as hunting associations, municipal governments, locally competent forest or water stream managers and residents.
- Basic photo documentation shall be taken during the assessment, preferably with equipment that allows geographical coordinates to be included to the meta-information of the image taken.

III. Evaluation of results and risk identification

- The guidance for this stage is based entirely on the procedures described in the individual KPD method sheets. It includes an assessment of the existing impacts and identification of the risk of impacts that may occur in the long-term.

IV. Proposal of mitigation measures

- The measures proposed are mainly of recommendatory nature. It contains the basic type of measure and initial specification (e.g., a two-sided fence on the road at km x-y with a fence height of 1.5 m). The proposals are not developed into design details.
- The proposal may also include a recommendation for further detailed investigation to clarify the issue and provide the necessary information for the final decision (e.g., chemical analysis of water from the road, detailed monitoring of animal movements, etc.)
- Detailed design and implementation of the measures shall be carried out after the audit.
- The individual proposed measures can be classified in terms of the possible implementation horizon as short-term (e.g., low-cost measures such as the addition of traffic signs, minor vegetation improvements, etc.), mid-term (e.g., speed limitation through physical measures, planting of guiding greenery, barriers for amphibians), and long-term (investment-based actions such as the construction of an ecoduct).

V. Conclusion – recap

- It is used for a comprehensive overview of the section and the proposed measures.
- A basic formal evaluation statement for each KPD is proposed:
  0 – the impact does not occur on the evaluated road,
  1A – the impact is present on the road and the current state meets the requirements of environmental protection,
  1B – the impact occurs on the road and the current condition is unsatisfactory – a list of noncompliant sites and an overview of the proposed measures are given.

Recommendations and discussion

The framework presented for EADI is a fully voluntary tool that does not introduce any formal approval processes. The EADI is designed as a methodological tool, which should be implemented by road managers to get a better and timely overview of environmental problems in the managed section of an existing road. It provides summary information on the environmental impacts of the road in question; it presents a list of optimisation measures as a basis for their further refinement and elaboration (more detailed studies, monitoring, project preparation, economic analyses, etc.). This is a recommended base for the preparation of investment plans for reconstruction and repair of the road sections in question; preparation for changes in maintenance technologies; summarisation of data on the optimisation measures implemented so far and their effectiveness as a basis for optimising the use of financial resources. EADI can be a suitable basis for the development of project documentation for the upcoming road reconstruction. It is assumed that in the most common cases the contracting authority and initiator of the audit will be the manager or owner of the road in question. The process of setting up the methodological framework itself makes maximum use of verified approaches and available information to avoid increasing the workload and financial demands of the whole process and duplication with other activities.

The basic aspects for setting priorities when assigning the sections to be subjected to environmental audit are upcoming road reconstruction; changes in maintenance technology; identified problems in environmental protection; immediate contact of the road with environmentally sensitive areas, or suggestions by state administration authorities or citizens. The implementation of the EADI is to be carried out only by professionally competent entities with practical experience in the field of environmental impact of road infrastructure.

As a new tool only finalised and approved at the end of 2021, the EADI is currently in the process of raising awareness of its existence and potential benefits. So far (summer 2023) full audits have been carried out on three sections of the road network (one each on a motorway, a national road and a Class II Road). Partial audits (consisting of 3 selected KPDs focusing on landscape fragmentation) have been prepared for the post-project evaluation of two national road constructions implemented under the Operational Programme Transport. The practical implementation of the individual recommendations from the audits is a subsequent task, which is the exclusive responsibility of the individual administrators of the evaluated infrastructure.

The proposal for a new environmental auditing tool is designed for use in the road transport sector. However, it is conceptualised in such a way that its analogy for other types of linear infrastructure is possible. But the specific problems of each mode of transport must be considered from the very beginning when creating such an analogy. Focus on the relevance of the individual KPDs and subsequently adapt their methodological sheets on the basis of the practices and methodologies used in the individual transport sectors. The similar situation is also with the regional transferability. Our methodology is adapted to the situation in the Czech Republic, but the basic concept of audit can be used in other countries as well. In this case, it will be necessary to

consider relevancy of specific problems in each region by the selection of individual KPDs and to revise their methodological part to the standards required in each country.

Conclusion

Ageing infrastructure is a global problem with potentially harmful consequences to the environment and innovative approaches are required to address this. The proposed framework provides a comprehensive and integrated approach to assessing the impacts of existing transport infrastructure on the surrounding environment. It sets up a step by step process, starting with the preparation of the background information for the assessment, the field survey procedure, the design of possible mitigation measures and their subsequent monitoring. Thus, EADI proposes a systematic approach to the preventive search for problem sites on the existing motorway and road network in relation to hitherto less monitored environmental components such as water, soil, biota, and landscape, with the aim of preparing proposals for practical and feasible optimisation measures that can be implemented primarily in the context of routine road repairs and reconstruction. Authors are convinced that EADI has the potential to introduce a systematic approach to assessing the impact of existing roads on the environment. It could also find its use in the post-project evaluation of newly constructed roads if the audit is extended to check compliance with the conditions set during the EIA process.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Data availability

All of the data that support the findings of this study are available in the main text.

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Appendix 1

Sample KPD methodological sheet – Permeability for Large Mammals

KPD B1: Permeability for Large Mammals

A. Name

Permeability for Large Mammals.

B. Component of Environment

Biota – fauna – mammals – population fragmentation.

C. Description

The sensitivity of different species to the barrier effect of roads varies. The most sensitive species are those that inhabit large ranges and the interconnection of sometimes strongly separated sub-populations is necessary to maintain their long-term existence. These animals include species collectively referred to as 'large mammals'. In the Czech Republic these include the brown bear (*Ursus arctos* L.), grey wolf (*Canis lupus* L.), the Eurasian lynx (*Lynx lynx* L.) and European elk (*Alces alces* L.) These species are protected under Act No. 114/1992 Coll. on the Protection of Nature and Landscape as specially protected species. Given the long-distance nature of migration, the protection of migration corridors must be addressed conceptually at national level.

For this purpose, the Agency for Nature Conservation and Landscape Protection of the Czech Republic has defined the so-called "Habitat of selected specially protected species of large mammals" (Romportl et al. 2017) as a protection tool. The Habitat includes areas allowing breeding and long term stay (so-called core areas) and migration corridors used for movement between the core areas. The map layer is provided in the system of spatial planning as a Planning Analytic Material (ÚAP), phenomenon 36b (AOPK 2023). Given that the ÚAP phenomenon 36b has the char-

acter of a relatively dense closed network with a total area of more than 25% of the Czech Republic, it is logical that motorway and road constructions must come into contact with this layer, and it is therefore necessary to address these conflicts. Each contact with this network must be assessed separately.

The assessment must be carried out on all motorways, expressways and other more than two-lane or fenced Class I roads. Class II and III roads and two-lane unfenced Class I roads are generally considered to be passable and do not require any construction measures. Nevertheless, it is recommended that even on these roads the contact points should be inspected in the field and assessed for any barrier.

D. Background materials

- map layer "Habitat of selected specially protected species of large mammals" – ÚAP phenomenon 36b.
- working map – contacts of the assessed road with the ÚAP phenomenon 36b.

Table A1. Migration object assessment form.

General description			
Object id:	Positioning on road [km]:	Type of object: • underpass/overpass • type category according to Hlaváč et al (2020)	
Landscape element	Most of the primarily designed structures lead another landscape element (e.g., dirt road, forest road, road, watercourse, etc.) across the road.		
map of the surrounding area			
Ecological characteristic of the site			
Importance of migration route	Description of migration routes at supra-regional, regional and local scales. Description of elements of the territorial system of ecological stability supporting animal migration.		
Landscape structure – supporting effects	It is a description of the elements that support migration, create migration pressure and increase the likelihood that the pathway will be used. These include the presence of a watercourse, valleys as natural migration routes for animals, the presence of green areas, food supply, etc.		
Disturbations	Description of the components that obstruct wildlife migration, create migration resistance, and reduce the likelihood that the migratory path will be used. These include the presence of transport, industry, mining, agricultural activities, proximity to settlements, etc.		
Technical characteristics of the site			
Type of wildlife passage	Description of the migration object given by the engineering design		
	Width (m):	Height (m):	Length (m):
Sub-bridge surface type	The nature of the surface must be natural as much as possible, the most suitable surface is grassed, natural soil without vegetation is also possible, paved concrete or asphalt surfaces, gravel, pebbles are completely inappropriate. Other potential disturbances associated with the sub-bridge should be mentioned.		
Shelters	The aim of the shelters is to compartmentalize the migratory object, to provide shelters for small animals and to facilitate their movement around the object (e.g., logs, branches, stones, etc.).		
Waterstream	The method of waterflow diversion determines whether the object will be usable for migration in addition to its hydrological function. As far as possible, it is advisable to leave the stream in its natural state and to leave a dry path, preferably along both banks of the stream.		
Surroundings			
Fencing	Wildlife that encounters road fencing often follow the fence and can be led to a migratory object. Fencing should be implemented on both sides of the object always from a migratory object to the next. Free endings of the fence without connections to migration objects are not recommended.		
Guidance vegetation	The aim is to guide the animals to the object.		
Summary			
Overall narrative evaluation of the migration object. Note on the proposed modifications to the object.			

E. Field survey

On the basis of the prepared background materials, a field survey will be carried out, including photographic documentation. There are two basic types of contacts that can occur in the working map:

a) corridor crossing – each crossing site is surveyed separately. Migration objects that meet the requirements for large mammals (animals of A category according to methodology Hlaváč et al. 2020) shall be described according to the outline in the Appendix 1: Table A1 above.
b) core area passage (contact section) – all migration objects that meet the parameters for Category A throughout the contact section shall be evaluated. This is a less common case, as core areas are mostly located in national parks and protected landscape areas where motorways and other capacity roads are rare. Distribution of wildlife passages (overall number and distance from each other) will be of the utmost importance for assessment.

F. Evaluation criteria

Basic concept for evaluation is that Class II and III roads and two-lane Class I roads – unless fenced or equipped with another impassable barrier – are not considered impassable migration barriers and no special migration facilities need to be implemented. On the other hand, motorways, three- and multi-lane Class I roads – and fenced roads of all classes – shall be considered an impassable barrier and suitable large mammal migration objects (Category A according to Hlaváč et al. 2020) shall be provided at the intersection with the migration corridor to ensure connectivity for wildlife.

Evaluation of the permeability (suitability) of the migration object:

- the passage must meet both technical and ecological parameters;
- minimal dimensions of the passage are set-up by Hlaváč et al. (2020):
  (i) overpass – central width min. 40 m;
  (ii) underpass – width 20–40 m, height 5–10 m, openness index 5–8;
- other technical parameters – nature of the underbridges, continuity of fencing, vegetation arrangements etc. – see comments in the Appendix 1: Table A1;
- basic ecological requirements:
  (i) minimisation of disturbing elements to avoid blocking the migration route;
  (ii) sub-measures – see Appendix 1: Table A1;
- parameters for contact sections (passage through the core area) – suitable wildlife passages for large mammals should be separated by a maximum of 5 km. This is an indicative figure; the whole situation needs to be assessed individually.

In most cases, the suitability or unsuitability of a migration object can be decided during a field survey based on the above criteria. In borderline and controversial cases, the literature should be consulted.

G. Proposed measures

It is dictated by nature conservation legislation that the migration passage for large mammals (as determined by ÚAP, phenomenon 36b) must be ensured. Therefore, if there are no suitable migratory features on the assessed road at the point of contact, they should be proposed.

Within the EADI, the proposal of new wildlife passage is conceptual and delineates only:

a) type of construction: partial modification of an existing facility or construction of a new facility;
b) location;
c) construction type (overpass/underpass) – categorisation according to the methodology by Hlaváč et al. (2020);
d) basic dimensions;
e) timeliness of the solution.

For the final design, it is advisable to prepare a detailed migration study before starting the investment preparation.

H. Conclusion

The result is a decision between three alternatives:

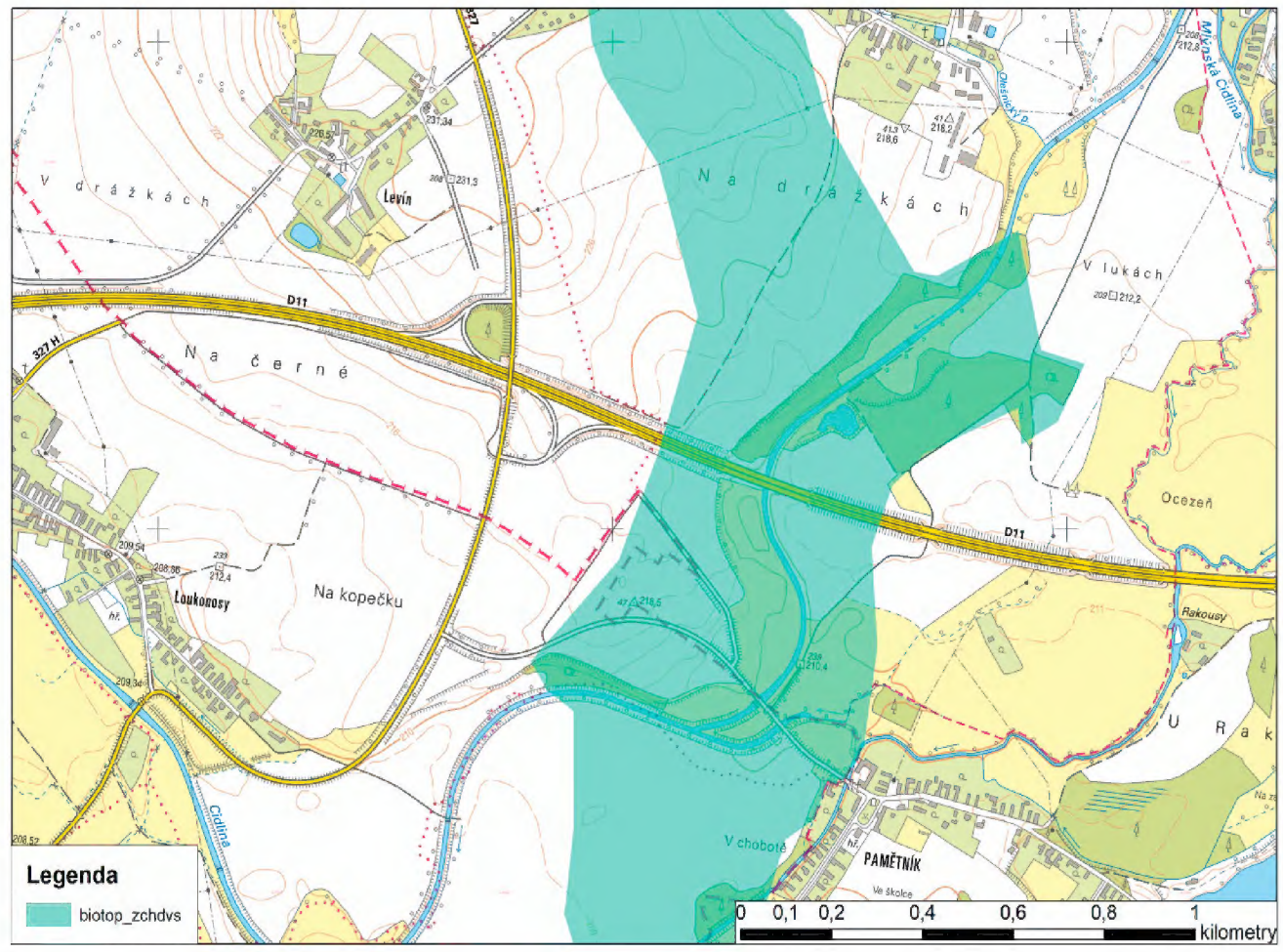
0 – the impact does not occur on the evaluated road,
1A – the impact is present on the road and the current state meets the requirements of environmental protection,
1B – the impact occurs on the road and the current condition is unsatisfactory – a list of noncompliant sites and an overview of the proposed measures are given.

Appendix 2

Table A2. Example of completed migration object assessment form.

General description		
Object id: D11-066	Positioning on road [km]: 62.2	Type of object: underpass P6
Landscape element	Watercourse – river Cidlina	

map of the surrounding area



Ecological characteristic of the site			
Importance of the migration route	This is a migration profile of supra-regional importance. The D11 motorway crosses the Biotope of selected specially protected species of large mammals. Furthermore, the regional biocorridor of the territorial system of ecological stability is designed under the bridge.		
Landscape structure – supporting effects	Along the Cidlina river there is a shrubbery in some places, to the north of the crossing point the mature trees turn into a small forest. Approximately 1.5 km from the building, a corridor leads through a larger forest in the south and north.		
Disturbations	The villages of Olešnice and Pamětník are more than 500 m away from the migration object.		
Technical characteristics of the site			
Type of wildlife passage	Wide bridge across the riparian floodplain on the lower reaches of the river		
	Width [m]: 200	Height [m]: 3.5	Length [m]: 30
Sub-bridge surface type	Natural clay surface of the underbridge. The Cidlina river is reinforced with stone under the bridge.		
Shelters for small animals	Shelters are not present.		
Waterstream	The Cidlina river is reinforced with stone under the bridge.		
Surroundings			
Fencing	Fencing is implemented on both sides, there is an incorrect design of the fence ending – leaving approximately 20 m gap between the end of the fence and the bridge railing		
Guidance vegetation	Guidance vegetation is not present.		
Summary			
An excellent, sufficiently dimensioned migration object for all categories of animals. Fence maintenance and technical solutions are important, it is necessary to complete the fencing so that it is properly attached to the bridge			

Figure A1. Migration Object nr. D11-066 north-west from Pamětník.

Figure A2. Inappropriate gap between the end of fencing and migration object nr. D11-066.